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ABSTRACT

Stop consonants after initial /s/ are standardly spelled as the unvoiced stops /p/, /t/, and /k/. Phonetically, however, they are similar to the voiced stops /b/, /d/, and /g/. Research suggests that many young children make consistent, reasonable, but unconventional, judgments about sounds and English spelling. This paper considers the case of the classification of stop consonants after initial /s/. The first experiment used a spelling test and a sound test. The spelling test asked 76 kindergarten and first-grade children what letters they used to spell the second sounds of syllables beginning with /s/-stop clusters. The sound test asked children to pronounce the syllables that remained when /s/ was deleted from syllables with initial /s/-stop clusters. This experiment found that some children consistently classify stops after /s/ as voiced. They spell /spo/ with B rather than P, and they state that /spo/ becomes /bo/ when s is deleted. Such nonstandard responses become less frequent as reading and spelling skills increase. In a second experiment, 20 university students were given spelling and sound tests that used the same lists of stimuli as Experiment 1. Experiment 2 confirmed that literate adults classify stops after /s/ as unvoiced, and that some adults are not very much aware of the phonetic similarity between stops after /s/ and voiced stops. (Author/AMH)

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Classification of Stops After /s/ by Children and Adults

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Abstract

Stop consonants after initial /s/ are standardly spelled as the unvoiced stops /p/, /t/, and /k/. Phonetically, however, they are similar to the voiced stops /b/, /d/, and /g/. Experiment 1 found that some kindergarten and first grade children consistently classify stops after /s/ as voiced. Thus, they spell /spo/ with B rather than P, and they state that /spo/ becomes /bo/ when the /s/ is deleted. Such nonstandard responses become less frequent as reading and spelling skill increase. Experiment 2 confirmed that literate adults classify stops after /s/ as unvoiced. Further, some adults are not very aware of the phonetic similarity between stops after /s/ and voiced stops.

Children's classifications of sounds differ, in some cases, from those of literate adults. Read (1975), for instance, found that some kindergarteners group the first sound of words like "truck" with /č/ (as in "cherry") rather than /t/ (as in "turkey"). Thus, they may spell "truck" with the letters CHR rather than the standard TR. While such a spelling seems odd to literate adults, it does make phonetic sense. /t/ followed by /r/ is somewhat affricated, or released slowly. It is thus similar to /č/, which is also affricated. Read's (1975) results suggest that many young children are accurate phoneticians who have yet to internalize the conventions of English spelling. Thus, their judgments about sounds are consistent and phonetically reasonable, but unconventional. If this suggestion is correct, the case of /t/ before /r/ may not be an isolated phenomenon. There may be other instances, as well, in which some children who are just learning to read and write classify sounds differently than do literate adults.

This paper considers one such case -- the classification of stop consonants after initial /s/. Literate adults consider words such as "spy", "sty", and "sky" to contain the unvoiced stops /p/, /t/, and /k/. They spell these words with the letters P, T, and K. Phonetically, however, stops after initial /s/ are similar to voiced stops. Klatt (1975) found that stops in /sp/ clusters have an average voice-onset time (VOT), or delay between closure release and onset of voicing, of 12 milliseconds. This value is closer to that found for initial /b/ (11 msec.) than for initial /p/ (47 msec.). Further evidence for the phonetic similarity of stops after initial /s/ to voiced stops comes from the results of a perceptual study (Reeds & Wang, 1961). When /s/ is removed from a tape-recorded token of a word such as "spy", English speakers identify the remaining word as "by" rather than "pie".

Given these phonetic facts, one might expect that some children who have not yet learned the standard spellings would classify stops after initial /s/ as voiced rather than unvoiced. Indeed, children learning to talk sometimes pronounce a word like "spoon" as "boon" (Ingram, 1974). First graders learning to write have been observed to spell "strongest" as SDROGIST (Chomsky, 1980) and "sky" as SGIE (Treiman, unpublished data). Systematic analyses of children's spontaneous productions and spellings of stops after /s/ have not, however, been done. For example, Read's (1975) study of preschoolers' invented spellings did not tabulate spellings of stops after /s/ separately from spellings of stops in other contexts.

One experiment (Fink, 1974) did address the issue of classification of stops after /s/ by asking second graders, third graders, and adults to spell nonsense words containing medial /s/-stop sequences. For the items containing /sp/ sequences, the children were more likely to spell the stops with B than with P. For adults, P responses predominated. However, there were few if any developmental differences for the items containing /st/ and /sk/ sequences. Fink's (1974) results may have been weak because the youngest subjects were second graders. By this level, children have probably internalized most of the spelling conventions of English.

Experiment 1 differed from Fink's (1974) previous study by including kindergarten and first grade children -- children who were just learning to read and write. This study focused on stops after initial /s/, and sought to determine how individual children classify these stops. It is likely that some children, perhaps those most influenced by English spelling, consistently classify these stops as unvoiced. Others may show an unconventional pattern, consistently judging them as voiced.

Two tasks were used to study children's classification of stops after /s/. The first was the spelling test. It asked what letters children used to spell the second sounds of syllables beginning with /s/-stop clusters. As Table 1 shows, children who classify the stops as voiced should use B, D, and G. Children who classify the stops as unvoiced should use P, T, and K. Both voiced and unvoiced responses are phonetically

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Insert Table 1 about here

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reasonable. A response such as G for /spo/, in contrast, is phonetically implausible and counts as an error. The second test used to study children's classifications was the sound test. This test asked children to pronounce the syllables that remained when /s/ was deleted from syllables with initial /s/-stop clusters. Children who classify the stops as voiced should give responses beginning with the appropriate voiced stops. Children who classify the stops as unvoiced should give responses beginning with the appropriate unvoiced stops. Also possible, as Table 1 shows, are errors.

Both the spelling test and the sound test were preceded by pretests to determine whether children possessed the necessary skills for the tests. The spelling pretest asked whether children knew the sounds of various letters, including the letters used to represent voiced and unvoiced stops, and whether they could use these letters to spell the initial segments of syllables such as /po/ and /blo/. The sound pretest asked whether children could delete the initial /s/ from syllables such as /slo/ and /swo/. With each of these syllables there is only one phonetically plausible response. Only children who passed the appropriate pretest took the spelling test and the sound test.

EXPERIMENT 1

Method

Subjects

A total of 76 subjects from five different kindergarten and first grade classes participated in the experiment. Relevant characteristics of each subject group are listed in Table 2. Note that all groups exceeded the reading

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Insert Table 2 about here

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and spelling levels expected for their grade. This was particularly true of the Montessori school students, who were from upper middle class and academic families. Also, public school 2 served a less privileged population than public school 1; this may explain why Group E did not perform better in the reading and spelling tests than Group D.

Stimuli

The spelling pretest and test employed 11 small cards, each with a capital letter printed on it. The letters used were P, T, K, B, D, G, S, L, W, M, and N. The stimuli for the spelling pretest were 25 spoken syllables beginning with /p/, /t/, /k/, /b/, /d/, /g/, /s/, /l/, /w/, /m/, /n/, /pr/, /pl/, /tr/, /tw/, /kr/, /kl/, /kw/, /br/, /bl/, /dr/, /dw/, /gr/, /gl/, and /gw/. There were six different forms of the pretest, with all syllables in each form having the same final vowel. The vowels used were /o/, /i/, /e/, /a/, /u/, and /ɔ/. The 25 syllables in each form were arranged in a random order, a different order for each of the six forms.

The stimuli for the sound pretest were 4 syllables beginning with /sl/, /sw/, /sm/, and /sn/. All four syllables in each form of the pretest had the same final vowel (/o/, /i/, /e/, /a/, /u/, or /ɔ/).

The spelling test and the sound test used the same lists of stimuli. As with the pretest, there were six different forms, one with each of the vowels /o/, /i/, /e/, /a/, /u/, and /ɔ/. Each form contained 22 syllables beginning with /s/ followed by one or more consonants. There were two syllables beginning with each of the clusters /sp/, /st/, /sk/, /spr/, /spl/, /str/, /skr/, /skl/, and /skw/. These 18 syllables are called critical syllables, as they allow either voiced or unvoiced responses. In addition, there were four control syllables, one beginning with each of /sl/, /sw/, /sm/, and /sn/. These syllables allow only one phonetically plausible response. The 22 syllables in each form were arranged in a pseudorandom order such that no two tokens of the same critical syllable occurred in succession and the four control syllables occurred at positions 5, 10, 15, and 20. The test lists were recorded in a sound-attenuated IAC booth by a female speaker. A professional microphone (Electro-Voice model #D054) and tape recorder (Ampex AG-500) were used. The lists were played back to the subjects over a Uher 4200 tape recorder.

Most critical syllables in each form of the spelling and sound tests were nonwords. Some of the real words (e.g., "spa") were probably unfamiliar both in written and spoken forms to most children. In fact, only one ("stay") was taught in the first grade in the reading series used in the two public schools. Thus, the children had not been taught to spell most of the syllables used in the spelling test. Also, most of the phonetically plausible responses for the sound test were nonwords. However, real word answers beginning with voiced and unvoiced stops were approximately equal in number across forms.

Procedure

Spelling pretest. The 11 printed letters were arrayed in haphazard fashion in front of the child, and the child was asked the sound of each. If any errors were made, the child was drilled on those letters until he or she performed correctly. Next, the experimenter pronounced the 25 pretest syllables of the form to which the child was assigned. The child repeated each syllable and then indicated the letter used to spell its initial sound. The child could respond either by pointing to one of the letter cards, which were left in view, or by saying the letter's name. The experimenter told the child that many of the "words" were not real, but to try to do as well as possible. If the child failed to reach a criterion of 18 or more correct responses on these 25 items, he or she did not take the spelling test. If the child reached criterion, he or she was drilled on any items on which errors had been made before proceeding to the spelling test.

Spelling test. The child heard the 22 tape-recorded test syllables of the form to which he or she was assigned. The child repeated each syllable after hearing it. Misrepetitions, which were very infrequent, were corrected. After repeating each syllable, the child was asked to indicate the letter used to spell its second sound. The experimenter told the child that the first letter was always S, and that he or she need only indicate the second letter. As in the pretest, the child could respond either by pointing to the appropriate letter or by saying its name. No feedback was provided on the child's choice of letters for the 18 critical syllables. For the four control syllables, the experimenter praised the child for right answers and corrected the child's errors.

Sound pretest. The child was shown a puppet and told that it hated the sound /s/. When it heard /s/ at the beginning of a word, it "stole"

that sound and said the word without the /s/. The experimenter demonstrated the puppet's responses to the four pretest stimuli, and the child repeated each response after the puppet said it. Test trials were given next. On each trial, the four stimuli were presented in a random order and the child tried to provide the puppet's responses. The experimenter corrected wrong answers and praised right answers. To make the task more enjoyable, the child was allowed to hold the puppet during the test trials and have it give the answers. The criterion was two successive correct trials on all four stimuli. If the child did not reach criterion in a maximum of six trials, he or she did not proceed to the sound test.

Sound test. The 22 tape-recorded test items were played to the child. The child first repeated each syllable and then gave the puppet's response. Misrepetitions of stimuli were corrected if they occurred. Feedback was given for the four control syllables but not for the 18 critical syllables.

Reading and spelling achievement tests. The reading and spelling subtests of the Wide Range Achievement Test (WRAT) were administered (Jastak & Jastak, 1978). The reading subtest asked children to recognize letters by form, name letters, and pronounce words. The spelling subtest asked them to copy non-letter forms, spell their name, and spell dictated words.

Each child was tested individually in a quiet room in his or her school or (in some cases) home over a period of several sessions. Each received the same form (i.e., the same vowel) in both the spelling and sound sections of the experiment. Assignment of subjects to forms and order of spelling and sound sections were balanced across subjects. In most cases, the spelling pretest and test (if the pretest was passed)

were given in one session, the sound pretest and test (if the pretest was passed) in another session, and the WRAT in a third session. The sessions ranged from about 15 to 30 minutes in length.

Results

Spelling pretest

Of the 76 subjects tested, 67 received a passing score on the spelling pretest. While the minimum passing score was 18 of 25 correct, the average score for these 67 children was 23.97 correct (s.d. = 1.71). Clearly, these children could spell voiced and unvoiced stop consonants in initial position with a very high degree of accuracy.

Spelling test

Responses to critical items were classified as voiced (V), the voiced stop with the appropriate place of articulation; unvoiced (U), the unvoiced stop with the appropriate place of articulation; or incorrect. (See Table 1 for examples.) Responses to control items were scored as correct or incorrect. As shown in the rightmost two columns of Table 3, children made relatively few errors on critical items and control items. The average error rate across all subjects was 14% for critical items and 13% for control items; these values did not differ significantly ($t(66) = .36$).

Insert Table 3 about here

Of primary interest here is V/(V + U), the proportion of voiced responses relative to all phonetically plausible responses on critical items. The value of V/(V + U) would be .00 for a subject who consistently spelled stops after /s/ in the conventional unvoiced manner and 1.00 for a subject who consistently gave voiced responses. The

distribution of V/(V + U) for all 67 subjects who took the spelling test was not normal. Using the method recommended by Hays (1973, pp. 725-727), the hypothesis of a normal distribution could be rejected at the .005 level ($\chi^2(3) = 15.75$). More subjects fell at the high and low extremes and fewer fell near the mean than would be the case with a normal distribution. For this reason, all statistical tests involving the variable V/(V + U) were nonparametric.

Table 3 shows that a majority of subjects followed the conventional pattern, spelling stops after /s/ as unvoiced. However, nine of the 46 children in Groups B, C, and D (end of kindergarten and beginning of first grade in public schools) preferred voiced to unvoiced spellings. That is, their values of V/(V + U) were greater than .50. In fact, two children -- one in Group B and one in Group D -- had values of V/(V + U) of 1.00. These children gave no conventional unvoiced spellings at all. Among children in Group A (Montessori school kindergarten) and Group E (end of first grade), all 21 preferred conventional spellings.

The nine children in Groups B, C, and D who preferred unconventional to conventional spellings performed well and consistently in the spelling test, not significantly less so than the 37 children in these same groups whose values of V/(V + U) were .50 or less. The former subjects made 3.11 errors (s.d. = 2.14) on the 18 critical items; the latter subjects made 2.59 errors (s.d. = 2.65). This difference is not significant ($t(44) = .55$). The two groups were also statistically indistinguishable in errors on control items, those for which only one answer was phonetically possible. The children whose values of V/(V + U) exceeded .50 had a mean of .78 errors (s.d. = .83) on these four items while the children whose values of V/(V + U) were .50 or less had a mean of .57 errors (s.d. = .93). This difference is not significant ($t(44) = .62$).

Finally, the subjects who preferred unconventional spellings did not make significantly more errors on the pretest than the other subjects. The means were 1.11 (s.d. = 1.54) and 1.00 (s.d. = 1.73) respectively; for the difference $\underline{t}(44) = .17$.

The five groups of subjects differed with respect to the average values of V/(V + U) by a Kruskal-Wallis test (correcting for ties, $\chi^2(4) = 21.62$, $p < .001$). Multiple comparisons (Hollander & Wolfe, 1973, pp. 124-129), performed at an experimentwise error rate of .05, showed that Group B differed significantly from both Group A and Group E. The other group differences did not reach significance.

The mean value of V/(V + U) was .18 for clusters with /p/, .15 for clusters with /t/, and .19 for clusters with /k/. These values did not differ significantly by a Friedman two-way analysis of variance by ranks (corrected for ties, $\chi^2(2) = 1.15$). However, V/(V + U) was higher for three-phoneme clusters (e.g., /spl/, /str/) than for two-phoneme clusters (e.g., /sp/, /st/). The mean values of V/(V + U) were .19 for three-phoneme clusters and .16 for two-phoneme clusters; these values differed significantly by a Wilcoxon test ($\underline{z} = 2.17$, $p = .03$, two tailed).

Children made a higher proportion of phonetically implausible responses on three-phoneme clusters (.18) than on two-phoneme clusters (.05) (by a Wilcoxon test $\underline{z} = 5.20$, $p < .00006$, two tailed). The additional errors on three-phoneme clusters occurred because children tended to leave out the second phonemes. The most frequent error on /spl/, for instance, was L. Thus, although children were instructed to spell the second consonant they sometimes spelled the third consonant instead.

Sound pretest

The sound pretest, which required children to delete the initial /s/ from syllables such as /slo/ and /swo/, proved difficult. Just 30 of the 76 subjects passed the sound pretest, and only these subjects took the sound test.

Sound test

The results of the sound test are shown in Table 4. The error rate on

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Insert Table 4 about here

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critical items, items which the children had not experienced during the pretest, was high -- approximately 30%. The error rate on control items, those on which the children had been trained, was less than 5%. The significant difference in error rates on the two types of items ($t(29) = 5.89$, $p < .0005$, one tailed) indicates that children had difficulty transferring the deletion of /s/ to new syllables. While the high error rate on critical syllables calls for some caution in interpreting the results of the sound test, findings discussed below show that many errors occurred because children had some, albeit imperfect, understanding of the task.

As with the spelling test, the distribution of V/(V + U) differed significantly from a normal distribution ($\chi^2(1) = 8.33$, $p < .005$). Table 4 shows that while most children had low values of V/(V + U), three preferred voiced to unvoiced responses. These children were found in Groups B, C, and D.

The three children who made more voiced than unvoiced responses did not make more errors on the sound test than 15 children in the same

groups with V/(V + U) values of .50 or less. The former subjects averaged 5.67 errors on critical items (s.d. = 6.14); the latter averaged 6.93 (s.d. = 5.15). This difference is not significant ($t(16) = .36$). That is, while the number of phonetically incorrect responses was high for both groups there is no evidence that the children who preferred unconventional responses made more errors than their classmates who preferred conventional responses. The group difference in control item errors was also insignificant. The children who preferred unconventional responses averaged .00 errors (s.d. = .00); their classmates averaged .33 errors (s.d. = .49). (For the difference, $t(16) = 1.16$.) Finally, the two groups did not differ in their mean number of errors on the pretest. The children who made a majority of voiced responses averaged 1.67 errors (s.d. = 1.53); the others averaged 1.00 errors (s.d. = 1.65) ($t(16) = .65$).

The differences among the five groups in average values of V/(V + U) did not reach the .05 level of significance by a Kruskal-Wallis test (correcting for ties, $\chi^2(4) = 8.95$, $p < .07$). However, the trend, as for the spelling test, was for the kindergarten groups to have the highest values.

The mean value of V/(V + U) was .14 for clusters with /p/, .06 for those with /t/, and .10 for those with /k/. A Friedman two-way analysis of variance by ranks indicated that these values did not differ significantly (corrected for ties, $\chi^2(2) = 2.30$; this analysis excludes 5 subjects whose values of V/(V + U) were undefined for one or more of the three cluster types). Nor was there a difference in the mean values of V/(V + U) for three-phoneme clusters (.11) and two-phoneme clusters (.10), as there was in the spelling test. Finally, the distribution of responses to critical items among the voiced, unvoiced, and error

categories was not significantly different when only the voiced response was a real word than when only the unvoiced response was a real word ($\chi^2(2) = 4.24$). This latter finding suggests that the sound test results were not contaminated by a preference for real word responses.

Nearly half (49%) of children's errors on critical syllables reflected the (correct) deletion of too many phonemes. For example, children often responded /lo/ to /splo/, deleting both /s/ and /p/ rather than just /s/. Similarly, they sometimes deleted both the /s/ and the stop when given two-phoneme clusters, responding with just the vowel. Thus, although the error rate on critical syllables was high, many errors did reflect a partial understanding of the task.

Relation between spelling and sound tests

Children who gave voiced responses on the spelling test tended to do so also on the sound test. For the 29 children with values of V/(V + U) on both tests, the Kendall rank correlation coefficient between the two scores, corrected for ties, was .43 ($z = 3.31$, $p = .0005$, one tailed). For these children, the mean value of V/(V + U) on the spelling test was .13 while the mean value of V/(V + U) on the sound test was .12. The significant correlation between the values of V/(V + U) on the two tests suggests that they are, to some degree, measuring the same thing -- the tendency to classify stops after /s/ in a phonetically reasonable but unconventional way. Several pieces of evidence, however, indicate that the spelling test provided a better measure of children's classifications than the sound test. First, the spelling pretest was easier than the sound pretest. Twenty-nine children passed both pretests; of those children who failed one pretest 38 failed the sound pretest and one failed the spelling pretest. This difference is highly significant by a McNemar test ($\chi^2(1) = 33.23$ using Yates' correction for continuity,

$p < .001$). Second, those children who passed both pretests made more errors on critical items on the sound test (4.90) than on the spelling test (1.48) ($t(28) = 4.83$, $p < .001$, two tailed).

Relation of performance on spelling and sound tests to reading and spelling scores

Children who were more advanced in reading and spelling, as measured by the WRAT test, were less likely to spell stops after /s/ as voiced. WRAT reading score correlated negatively with V/(V + J) in the spelling test (Kendall rank correlation coefficient τ corrected for ties = -.30, z = -3.62, $p < .0002$, one tailed). Likewise, WRAT spelling score correlated negatively with V/(V + U) in the spelling test (τ = -.26, z = -3.07, $p < .002$, one tailed). That is, as reading and spelling skill increased, the tendency to spell stops after /s/ unconventionally decreased. Within this population, there was no correlation between a child's age and his or her value of V/(V + U) on the spelling test (τ = .01). The correlations between WRAT reading and spelling scores and V/(V + U) on the sound test were also negative, but did not reach significance, possibly due to the smaller number of subjects who took the sound test and/or to its presumably lower reliability. The Kendall rank correlation between WRAT reading score and V/(V + U) on the sound test was -.13 (z = -.97); that between WRAT spelling score and V/(V + U) on the sound test was -.20 (z = -1.53, $p < .07$, one tailed).

Table 5 depicts the relation between reading and spelling level and performance on the /s/ cluster spelling test in terms of the numbers of children at each reading level who had values of V/(V + U) of .50 or less and of .51 or more. Among children reading at the first grade level, 20% gave a majority of voiced responses; this percentage decreased to 13% for those reading at the second grade level and 0% for children reading at

the third grade level or above. The figures for spelling level are comparable.

Insert Table 5 about here

Discussion

The results of Experiment 1 show that some children classify stops after initial /s/ with the voiced stops /b/, /d/, and /g/ rather than with the unvoiced stops /p/, /t/, and /k/. This classification emerges when they are asked to spell syllables containing /s/-stop clusters and when they are asked to delete /s/ from these syllables. Children who categorize stops after /s/ with voiced stops presumably focus on phonetic features such as VOT on which stops after /s/ are more similar to voiced stops than to unvoiced stops (Klatt, 1975). Thus, consistent with the view of Read (1975), some young children are accurate phoneticians. In the case of stops after initial /s/, as in the case of /t/ before /r/, children who do not yet know the conventional English spellings sometimes make unconventional but phonetically reasonable classifications.

While children may be accurate phoneticians, the right tasks are needed to draw out their phonetic abilities. The spelling test of Experiment 1 proved better for this purpose than the sound test. One likely reason for the difference was that the spelling test gave children a choice of 10 responses. The response set for the sound test was not constrained. It is also possible (as suggested by Elkonin, 1973) that children most readily indicate their knowledge about sounds when visual aids -- in this case the letters corresponding to the sounds -- are provided. Purely auditory tasks, such as the deletion of an initial phoneme, may be more difficult. Indeed, Bruce (1964), who first reported

on the difficulty of deletion tasks, stated that children could not perform these tasks until they reached a mental age of seven.

The results of Experiment 1 suggest that literacy exerts a strong effect on the categorization of stops after /s/. While some children in kindergarten and the beginning of first grade classified stops after initial /s/ as voiced, the tendency to do so diminished as reading and spelling skill increased. By the end of the first grade year, almost all of the children's responses were conventional. Indeed, standard spelling may have affected the responses of even the youngest and least literate subjects tested here. Given the prevalence of printed words such as STOP, and given the fact that even preschoolers attend to and learn about the print in their environment (e.g., Harste, Burke, & Woodward, 1982), many subjects may have classified the stops as unvoiced based on a knowledge of standard spelling. In fact, it would be difficult to find children who could perform the present tasks and who were completely naive with respect to the conventional spellings of stops after /s/.

To study possible effects of literacy on the classification of specific phonemes after /s/, the reading series used in the two public schools involved in Experiment 1 was examined. (Data on the reading materials used by the Montessori school students were not available.) This series taught 21 words containing initial /s/-stop clusters in the first grade. Of these, more contained /t/ than either /p/ or /k/ ($\chi^2(2) = 13.71$, $p < .005$), and more had a single consonant than two consonants after the /s/ ($\chi^2(1) = 3.86$, $p < .05$). These same patterns held true for the words taught at the second grade level, as well. Thus, if the public school students' reading instruction were confined to the classroom, they would be more familiar with conventional spellings in the case of /st/ than /sp/ and /sk/, and in the case of two-phoneme clusters than

three-phoneme clusters. Indeed, conventional spellings were found to be more frequent with two-phoneme clusters than with three-phoneme clusters. The observed difference may reflect a greater exposure to two-phoneme clusters. There was also a tendency for children to make more conventional spellings with /st/ than with /sp/ or /sk/, but it was not significant. Therefore, no firm conclusions can be drawn about phoneme-specific effects of reading and spelling experience on children's classifications of stops after /s/.

Experiment 2 sought to further study the effect of literacy on the classification of stops after /s/. Its first goal was to verify that college students give unvoiced responses on the spelling and sound tests. Its second and more important aim was to study the degree to which these literate subjects can disregard spelling conventions and focus on the phonetic qualities of stops after /s/.

EXPERIMENT 2

Method

Subjects

Twenty-four members of a subject pool of Indiana University students participated in the spelling test. Twenty-four different students participated in the sound test. All subjects were native speakers of English, and none had previous training in linguistics or phonetics.

Stimuli

The spelling and sound tests used the same lists of stimuli that were employed in Experiment 1. The spelling test also used the cards with the letters P, T, K, B, D, G, S, L, W, M, and N printed on them, as in Experiment 1.

Procedure

Spelling test. The letter cards were arranged in haphazard fashion in front of the subject. The S card was placed to the side, and the subject was told that he or she would hear syllables that began with the letter S. The 22 tape-recorded test syllables of the form to which the subject was assigned were played. The subject repeated each one and then indicated its second letter. Any errors were corrected. For each critical syllable the experimenter then asked, "If you couldn't use the letter that you picked, what other phonetically plausible letter could you use?" The subject was to pick as a second choice one of the 10 letters other than S on the cards. No feedback was provided.

After the test list was completed, the experimenter explained the appropriate second choice for one of the critical syllables -- that beginning with /sp/, /st/, or /sk/. On this demonstration trial, the experimenter used nontechnical language and physical demonstrations (e.g., having the subject hold a hand in front of his or her mouth to sense aspiration) to explain that the stop after /s/ was similar to the voiced stop. After explaining the second choice for one place of articulation, the experimenter asked the subject to use the same principles to choose an alternate letter (again from the 10 provided) in the other two cases. These trials will be called generalization trials.

Four subjects were assigned to each form (i.e., each vowel) of the test list. Eight were assigned to each place of articulation for the demonstration trial.

Sound test. The 22 tape-recorded test items were played. The subject was asked to repeat each one and then say it without the /s/. Any errors were corrected. For each critical syllable the experimenter then asked, "If you couldn't give that answer, what other phonetically plausible answer could you give?" No feedback was provided.

After the test list was completed, a demonstration trial and two generalization trials were given, as for the spelling test. Four subjects were assigned to each form of the test list and eight were assigned to each place of articulation for the demonstration trial.

Results

Spelling test

Subjects' first responses to critical items were almost invariably the standard spellings. The average value of V/(V + U) was .007 (s.d. = .019), and there was an average of .33 errors (s.d. = .56) on critical items. Most of these errors arose when subjects spelled the third consonant rather than the second. As Table 6 shows, performance varied greatly when subjects were asked to give an alternate response for the critical items. Some subjects were able to access the

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Insert Table 6 about here

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nonstandard but phonetically plausible voiced spellings. ("They are the only logical alternatives", one said.) Other subjects were completely unable to do so. Six did not produce any correct alternate spellings. Subjects tended to give more correct answers to clusters containing /p/ (.53 correct) than to clusters containing /t/ or /k/ (.33 and .39 correct, respectively). However, this trend did not reach significance by a Friedman two-way analysis of variance by ranks (corrected for ties, $\chi^2(2) = 4.33$, $p < .1$).

All but one subject appeared to understand the demonstration trial, on which the possibility of a voiced spelling was explained for one place of articulation. Subjects varied, again, in their ability to generalize to the other two places of articulation. Proportion correct on the

generalization trials ranged from .00 (one subject) to 1.00 (fifteen subjects). The mean proportion correct was .79 (s.d. = .29).

Sound test

Subjects' first responses reflected a categorization of stops after /s/ as voiceless. The mean value of V/V + U was .005 (s.d. = .016), and there was an average of .75 errors (s.d. = 1.42) on the 18 critical items. A majority of these errors reflected the correct deletion of too many phonemes. As Table 6 shows, subjects performed poorly when asked to give alternate answers. Proportion correct ranged from .00 to .67. Performance varied significantly with place of articulation: .23 correct with /p/, .17 with /t/, and .06 with /k/. A Friedman two-way analysis of variance by ranks showed that these values differed significantly (corrected for ties, $\chi^2(2) = 13.25$, $p < .005$). Multiple comparisons (Hollander & Wolfe, 1973, p. 151) showed that subjects did significantly better with /p/ than with /k/ ($p < .01$); the other comparisons were not significant.

All but two subjects appeared to understand the demonstration trial. Proportion correct on the generalization trials ranged from .00 (thirteen subjects) to 1.00 (four subjects), with a mean of .31 (s.d. = .38).

Comparison between spelling and sound tests

Subjects in the spelling test gave more correct alternate responses than subjects in the sound test (by a Mann-Whitney test $z = 2.21$, $p = .03$, two tailed). In addition, spelling test subjects performed better on the generalization trials than sound test subjects ($z = 3.72$, $p < .0002$, two tailed). These differences probably arose because subjects in the spelling test had only 10 responses from which to choose, whereas subjects in the sound test had no constraints on possible responses. In a pilot study in which six subjects were allowed to choose

any letter as an alternate response in the spelling test the mean proportion correct was .13, a figure almost identical to that observed in the sound test (.14).

Discussion

The results of Experiment 2 confirm that literate adults classify stops after initial /s/ as voiceless, whether they are asked to spell those stops or to pronounce the syllable that remains when /s/ is deleted. The results further show that some adults have difficulty attending to the phonetic qualities of stops after /s/. When not permitted to give the conventional voiceless responses, some subjects fail to generate plausible alternatives. Even after the alternative for one place of articulation has been explained, some subjects have difficulty generalizing to the other two places of articulation. Apparently, the classification of stops after /s/ as voiceless is so automatic that some adults do not readily perceive that these stops are phonetically similar to voiced stops.

The results of Experiment 2 should not be taken to indicate that certain literate adults cannot access the phonetic qualities of stops after /s/. With more instruction, subjects would surely have given more correct alternate responses. Indeed, subjects averaged almost 80% correct when the response set was constrained and when the correct answer had been explained for one place of articulation (i.e., in the generalization trials of the spelling test.) The results do imply that access to phonetic features is difficult for a fair number of literate and linguistically-untrained people. Previous investigators (e.g., Healy & Levitt, 1980; Jenkins, Foss, & Greenberg, 1968) have also noted adults' difficulties in accessing phonetic features, and have suggested that these difficulties diminish when subjects are made to attend to the way

in which they articulate sounds. That subjects in the present study tended to perform better with /p/ than with /t/ or /k/ suggests that attention to articulation may be easier when the critical events occur further forward in the mouth. This possibility deserves further exploration.

GENERAL DISCUSSION

Stops after initial /s/ have long been problematic for linguists. The difficulty arises because voiced and unvoiced stops do not contrast in this context, as they do in other contexts. Since stops after initial /s/ are in complementary distribution with both voiced and unvoiced stops, it is unclear how they should be classified. On phonetic grounds, stops after initial /s/ are not identical to either voiced or unvoiced initial stops. However, they may be more similar to the former than to the latter (Klatt, 1975; Reeds & Wang, 1961). On distributional grounds, it has been argued that stops after initial /s/ should be considered allophones of unvoiced stops (e.g., Hockett, 1955, p. 159). Since unvoiced stops but not voiced stops occur after /s/ in syllable-final position (e.g., /asp/ is a possible English syllable but /asb/ is not), pattern congruity will be served if stops after initial /s/ are also classified phonologically as unvoiced. That is, a phonological system in which all stops after /s/ are unvoiced is simpler and more economical than one in which the categorization of stops after /s/ depends on their position.

If we assume, with Hockett (1955), that stops after /s/ are phonologically unvoiced for adults, there are two hypotheses about why some children give voiced responses in the present tasks. One hypothesis is that these children's phonological systems are different from those of adults. Perhaps these children have not had enough experience with the

distributional facts of spoken language to develop a mature phonological system. Or, perhaps pattern congruity does not weigh as heavily for children as for adults, causing children's assignments of phones to phonemes to be governed largely by phonetic similarity. A second hypothesis about why some children respond unconventionally in the spelling and sound tasks is that these children's responses reflect the phonetic rather than the phonological level. In this view, children's phonological representations of stops after /s/ may be identical to those of adults. However, some children think that spelling represents the phonetic level of language rather than (as English spelling more nearly does) the phonological or even the morphological level. Likewise, these children's responses in the /s/ deletion task may be governed by phonemic rather than phonological considerations.

Further research will be needed to decide between these two hypotheses. Despite these unaswered questions, however, the results presented here have practical significance. Some kindergarten and first grade children spell stops after /s/ as voiced; some linguistically-untrained adults are not very aware of the phonetic similarity between stops after /s/ and voiced stops. Misunderstandings might well arise if a child who spelled stops after /s/ unconventionally were paired with a parent or a teacher who failed to understand the logic behind the child's "error".

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Table 1

Examples of Stimuli and Possible Responses

in Spelling and Sound Tests

Stimulus	Spelling test responses			Sound test responses		
	Voiced	Unvoiced	Error	Voiced	Unvoiced	Error
/spo/	B	P	G	/bo/	/po/	/to/
/splo/	B	P	T	/blo/	/plo/	/lo/
/sto/	D	T	K	/do/	/to/	/o/
/stro/	D	T	B	/dro/	/tro/	/bro/
/sko/	G	K	P	/go/	/ko/	/sko/
/skwo/	G	K	[illegible]	/gwo/	/kwo/	/mo/

Table 2

Characteristics of Experiment 1 Subjects

Group	N	Grade	School	Time of testing	Mean age (yrs., mos.)	Mean grade equivalents Reading	Spelling
A	11	Kind.	Private Montessori school	Fall and Spring	5,5	2.6	2.1
B	18	Kind.	Public school 1	Spring	6,2	1.8	1.5
C	13	Kind.	Public school 2	Spring	6,0	1.6	1.5
D	22	1st	Public school 1	Fall	6,9	2.8	2.6
E	12	1st	Public school 2	Spring	7,0	2.4	2.6

Table 3

Results of Experiment 1 Spelling Test

Group	N passing pretest	N with V/(V+U) in range: .00-.25	.26-.50	.51-.75	.76-1.00	Mean of V/(V+U)	Mean # errors, critical items	Mean # errors, control items
A	10	10	0	0	0	.00(.00)	2.90(2.60)	.40(.70)
B	14	7	1	2	4	.43(.38)	3.50(2.47)	.43(.65)
C	10	7	2	1	0	.18(.20)	3.70(3.30)	1.80(.92)
D	22	16	4	1	1	.20(.26)	1.73(1.88)	.18(.50)
E	11	10	1	0	0	.04(.09)	1.27(3.35)	.27(.65)
All	67	50	8	4	5	.19(.28)	2.49(2.71)	.52(.84)

Note. Standard deviations are in parentheses.

Table 4

Results of Experiment 1 Sound Test

Group	N passing pretest	N with V/(V+U) in range: .00–.25	.26–.50	.51–.75	.76–1.00	Mean of V/(V+U)	Mean # errors, critical items	Mean # errors, control items
A	3	3	0	0	0	.09(.10)	3.33(1.53)	.00(.00)
B	7[a]	5	0	1	0	.15(.27)	10.43(5.86)	.57(.53)
C	2	1	0	0	1	.51(.46)	3.50(4.95)	.00(.00)
D	10	8	1	1	0	.13(.21)	5.90(5.59)	.30(.48)
E	8	8	0	0	0	.00(.00)	1.88(1.36)	.00(.00)
All	30	25	1	2	1	.12(.23)	5.47(5.34)	.23(.43)

Note. Standard deviations are in parentheses.

[a]One subject passed the pretest but made no appropriate V or U responses. This subject's data are not included in those columns that involve V/(V+U).

Table 5

Relation between Reading and Spelling Level and V/(V+U) in Spelling Test in Experiment 1

	Number of children with V/(V+U) .00-.50	Number of children with V/(V+U) .51-1.00
Reading level		
1st grade	14	5
2nd grade	28	4
3rd grade and above	16	0
Spelling level		
1st grade	18	6
2nd grade	36	3
3rd grade and above	4	0

Table 6

Proportion Correct (i.e., Voiced) Alternate Responses in Experiment 2

	N with proportion correct in range:				Mean
	.00-.25	.26-.50	.51-.75	.76-1.00	
Spelling test	8	7	3	6	.43 (.36)
Sound test	21	2	1	0	.14 (.15)